

Original Article

Neurologic injury in snowmobiling

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Abstract

Background: Snowmobiles are increasingly popular recreational, all-terrain utility vehicles that require skill and physical strength to operate given their inherent maneuverability, acceleration, and top speed capabilities. These same characteristics increase the risk of injury with the operation of these vehicles, particularly neurological injury. We characterize our series of 107 patients involved in snowmobiling accidents.

Methods: From January 2004 to January 2012, all snowmobiling-related injuries referred to our regional trauma center were reviewed. Information had been recorded in the hospital's trauma registry and medical records were retrospectively reviewed for data pertaining to the injuries, with particular emphasis on neurological injuries and any associated details.

Results: A total of 107 patients were identified. Ninety percent of injured riders were male. The mean age was 34.4 years (range 10-70), with 7% younger than age 16. The mean Injury Severity Score was 12.0 ± 0.69 (range 1-34). Although not documented in all patients, alcohol use was found in 7.5% of the patients and drug use found in one patient. Documentation of helmet use was available for only 31 of the patients; of which 13% were not helmeted. Causes included being thrown, flipped, or roll-over (33%), striking a stationary object (27%), being struck by a snowmobile (9%), striking another snowmobile (5.5%) or a car, train, or truck (5.5%), being injured by the machine itself (9%), other (2%) or unspecified (18%). Head injuries occurred in 35% patients, including concussion, subarachnoid hemorrhage, subdural hematoma, contusion, and facial/skull fracture. Spinal fractures occurred in 21% of the patients. Fractures to the thoracic spine were the most common (50%), followed by the cervical (41%) and lumbar (36%) spine. There were also three brachial plexus injuries, one tibial nerve injury, and one internal carotid artery dissection. Average length of stay was 4.98 ± 0.56 days. Disposition was home (78%), home with services (12%), rehabilitation placement (9%), and one death. Details regarding other systemic injuries will also be reviewed.

Conclusions: Snowmobiles are a significant source of multi-trauma, particularly neurological injury. Neurosurgeons can play key roles in advocating for neurological safety in snowmobiling.

Key Words: Brain injury, neurological sports medicine, snowmobile, spine injury, trauma, traumatic brain injury

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INTRODUCTION

In 1923, Joseph-Armand Bombardier introduced the first prototype of the snowmobile in Valcourt, Quebec, Canada.^[12,18] Originally intended by Bombardier as a means of personal transport for fishing and hunting during the winter months, it quickly evolved into a work vehicle, being used as a school bus, ambulance, snow plough, and even armored troop carrier during the world wars.^[18] Today, snowmobile use is even broader still and notably has become an increasingly popular recreational, all-terrain utility vehicle.

In 2004, Carr *et al.* published a comprehensive 10-year retrospective review of neurologic injury and death resulting from all-terrain vehicle crashes in West Virginia.^[6] This study was in response to an observed rise in the incidence of brain and spine injuries as well as fatalities due to all-terrain vehicle use, and had the goal of identifying patterns of injury mechanism and type and preventable risk factors that improved legislation could eliminate.^[6]

As recreational all-terrain vehicle use in West Virginia has become greatly popular, so too has the sport of snowmobiling in many cold-weather climates including Upstate New York.^[1,8,9,11,13,21-23] As of October 2010, New York State had over 130,000 snow machines registered,^[1] reflecting the increased popularity of snowmobiles as a wintertime recreational vehicle. Given the inherent maneuverability, acceleration, and top speed capabilities of these vehicles, it is easy to understand why this sport is growing so rapidly, but as a result of these same characteristics there is an increased risk of injury with operation of these vehicles, particularly neurologic injury.^[2,3,6-11,14,17,19-21,23,25]

The present study is a retrospective review of trauma registry data, as well as patient records at the University of Rochester Medical Center in Rochester, New York between January 2004 and January 2012 identifying snowmobile-related injuries. Given the long winter season in Western New York State, and the increasing participation in the sport of snowmobiling among the patient population our level I trauma center serves, we sought to characterize injury in terms of patient demographics, mechanism of injury, spectrum of neurologic and nonneurologic injury, and disposition and patient outcomes. We also reviewed the literature to determine if common risk factors for snowmobile use were shared by our study, and if so what regulatory or legislative action has or could be taken to alleviate this risk and improve the safety of this popular winter pastime.

PATIENTS AND METHODS

This study involves the retrospective review of trauma registry data for both adults and children less than

18 years of age who were referred for treatment at the University of Rochester Medical Center in Rochester, New York with snowmobile-related injuries between January 2004 and January 2012. This time frame was used to adequately assess trends and evaluate outcomes surrounding snowmobile-related injury across many winter seasons. The University of Rochester Medical Center Research Subjects Review Board approved this study (RSRB00039900). Information obtained from trauma registry data as well as from patient records from the University of Rochester Medical Center system, including Strong Memorial Hospital and Highland Hospital, was retrospectively reviewed for data pertaining to the injuries, with particular emphasis on neurological injuries and any associated details.

Data acquired regarding these patients with snowmobile-related trauma included patient demographics, mechanism of snowmobile injury including helmet-use status, spectrum of neurologic injury, spectrum of nonneurologic injury, and disposition and outcomes following hospital stay. Types of neurologic injury were classified as spinal, head, peripheral nerve, and vascular injuries. Types of nonneurologic injury were classified as orthopedic, abdominal, or thoracic in origin. Each injury was counted individually, and if there were multiple injuries within a single patient each injury was counted independently. The objective severity of injuries was evaluated with the Injury Severity Score (ISS). Using this system, the injuries from seven different body regions (head, neck, abdomen, pelvis, thorax, extremities, and external tissues) were standardized and scored from minor (1 point) to critical (5 points).^[16] The ISS was generated by adding the squares of the values given for a patient's three worst injuries (i.e., $a^2 + b^2 + c^2 = \text{ISS}$).^[16]

Snowmobile registration and statewide injury data were obtained from the New York State Office of Parks, Recreation, and Historical Preservation (OPRHP).

RESULTS

Demographics

A total of 107 snowmobile-related trauma patients were identified. In agreement with other mechanisms of trauma, 90% of riders injured due to snowmobile-related incidents were male. The mean age was 34.4 years (range 10-70), with 7% younger than age 16 [Table 1]. The mean ISS was 12.0 ± 0.69 (range 1-34).

Statewide registration information was obtained from the New York Office of Parks, Recreation, and Historical Preservation for the last 13 years [Table 2]. The average number of injuries per year was 340 ± 41 . The median number of injuries was 316. If restricted only to the years encompassing our study period, those statistics change to 299 ± 37 and 294 injuries, respectively. The registrations for the six counties in the study hospital's catchment

area were then parsed out for the 2012-2013 season (prior years' data were unavailable). A total of 2194 new registrations and 9324 renewals were processed for this season in those counties. The overwhelming majority of these registrations were associated with snowmobiling clubs.

Risk factors

Of the trauma registry data and patient records reviewed, documentation of helmet use was available for only 31 of the 107 patients; of which 13% were not helmeted. Again, although not documented in all patients, ethanol use was found in 7.5% of the patients where blood alcohol content was recorded, and drug use found in one patient where the data was available.

Mechanisms of injury

Most snowmobile-related injuries encountered could be attributed to one of several mechanisms including being thrown from the snowmobile or having the snowmobile flip or roll-over [$n = 35$ (33%)], striking a stationary object [$n = 29$ (27%)], being struck by a snowmobile [$n = 10$ (9%)], striking another snowmobile [$n = 6$ (5%)], striking a car, train, or truck [$n = 6$ (5%)], being injured by the machine itself [$n = 10$ (9%)], other [$n = 2$ (2%)], or unspecified [$n = 19$ (18%)]. In none of the incidents reviewed was falling through ice or drowning attributed as the causal etiology of injury [Table 3].

Spectrum of neurologic and nonneurologic injury

Neurologic injuries were categorized and head injuries occurred in 36% of patients ($n = 39$ patients). The most common injury was concussion [$n = 33$ (31%)]. Other cranial vault injuries included subarachnoid hemorrhage [$n = 2$ (2%)], subdural hematoma [$n = 1$ (1%)], intraparenchymal hemorrhage [$n = 2$ (2%)], and facial/skull fractures [$n = 9$ (8%)] [Table 4]. Spinal fractures [Table 5] occurred in 21% of patients ($n = 22$). Fractures to the thoracic spine were the most common, accounting for 50% of these cases, followed by the cervical (41%) and lumbar spine (36%). Most patients (32%) only required nonoperative management with bracing and pain control for their one or two column injuries. One was treated with a halo for a C5/6 compression fracture. Three patients (9%) required operative repair of their fracture: One had an anterior discectomy with fusion for C6/7 facet dislocation, one had a C2-T4 posterior fusion for C6/7 fracture-dislocation, and one had a T3-9 fusion with cables. Peripheral nerve injuries included three brachial plexus injuries and one tibial nerve injury. There was also one vascular injury involving an internal carotid artery (ICA) dissection.

Details regarding nonneurologic systemic injuries were also reviewed and were broken into three categories including orthopedic, abdominal, and thoracic injuries. The spectrum of orthopedic injury included upper

Table 1: Demographics and disposition of patients with snowmobile trauma

Metric	Number (%) (if not specified)
Age (years with range)	34.4 (10-70)
Male gender	96 (90)
Patients < 18 years of age	10 (9)
Average length of stay (days)	4.98 ± 0.56
Disposition	
Home	83 (78)
Home with services	13 (12)
Rehabilitation	10 (9)
Placement	
Death	1 (1)

Table 2: New York state snowmobile injury data by winter season data obtained from the office of parks, recreation and historical preservation

Season	Registrations	Injuries per 1000 registrations	Number of Injuries*
2000-2001	146,662	3.13	459
2001-2002	151,287	2.09	316
2002-2003	172,164	3.86	665
2003-2004	163,635	3.1	507
2004-2005	155,000	2.89	448
2005-2006	149,610	1.57	235
2006-2007	130,502	2.25	294
2007-2008	128,283	2.46	316
2008-2009	136,471	2.37	323
2009-2010	131,664	2.23	294
2010-2011	134,442	2.05	266
2011-2012	90,433	1.12	101
2012-2013	116,725	1.65	193

*Number calculated by dividing the number of injuries per 1000 registrations by 1000 and multiplying by the number of registrations (rounded to the nearest whole number). Data from the years included in this study are given in bold

Table 3: Mechanism of snowmobile injury

Reported reason	Number (%) of patients (N=107)
Thrown/flipped/rolled-over	35 (33)
Struck stationary object	29 (27)
Injured by the snowmobile	10 (9)
Struck another snowmobile	6 (5)
Struck another vehicle	6 (5)
Other	2 (2)
Unspecified	19 (18)

extremity [$n = 17$ (16%)], lower extremity [$n = 6$ (34%)], and hip and pelvis [$n = 6$ (6%)]. Abdominal injury was predominantly to the solid organs of the peritoneal cavity and retroperitoneal cavities including the liver [$n = 4$ (4%)], the spleen [$n = 13$ (12%)], the kidneys [$n = 2$ (2%)], and other [$n = 2$ (2%)]. Lastly, thoracic trauma contributed greatly to the morbidity associated with snowmobile-related accidents and included

pneumothorax and hemothorax [$n = 20$ (19%)], pulmonary contusion [$n = 17$ (16%)], rib fractures

[$n = 31$ (29%)], clavicle fracture [$n = 12$ (11%)], and scapula fracture [$n = 3$ (3%)] [Table 6].

Table 4: Neurologic injuries resulting from snowmobile accidents

Injury	Number (%) of patients ($N=107$)
<i>Spinal column</i>	22 (21)
Cervical spine	9 (41)
Thoracic spine	10 (50)
Lumbosacral spine	8 (36)
Requiring surgery	3 (14)
<i>Cranial vault/brain</i>	39 (36)
Concussion	33 (85)
Subdural hematoma	1 (3)
Intraparenchymal Hemorrhage	2 (5)
Subarachnoid Hemorrhage	2 (5)
Facial/skull fracture	9 (23)
<i>Peripheral nerve</i>	4 (4)
Brachial plexus	3 (75)
Tibial nerve	1 (25)
<i>Cerebrovascular</i>	1 (1)

Table 5: Spinal injuries resulting from snowmobile accidents

Injury	Number (%) of patients ($N=22$)
Vertebral body	6 (27)
Spinous process	6 (27)
Transverse process	10 (45)
Facet	3 (14)
<i>Interventions</i>	10 (45)
Bracing	7 (32)
Halo	1 (5)
Surgery	3 (14)

Table 6: Nonneurological injuries resulting from snowmobile accidents

Injury	Number (%) of patients ($N=107$)
<i>Orthopedic</i>	
Upper extremity	17 (16)
Lower extremity	36 (34)
Hip/pelvis	6 (6)
<i>Abdominal</i>	
Liver	4 (4)
Kidney	2 (2)
Spleen	13 (12)
Other	2 (2)
<i>Thoracic</i>	
Pulmonary contusion	17 (16)
Pneumo-/hemothorax	20 (19)
Rib fractures	31 (29)
Clavicle fracture	12 (11)
Scapula fracture	3 (3)

Disposition and patient outcomes

Average length of stay (LOS) due to snowmobile trauma-related admission was 4.98 ± 0.56 days. Disposition was home in 78% of patients, home with services in 12% of patients, to a dedicated rehabilitation facility in 9% of patients, and there was one death in this series of 107 patients [Table 1].

DISCUSSION

This study's 107 snowmobile-related traumas represented approximately 3% per year of the total state's snowmobile traumas, and less than 1% of total registrations per year in the region, when extrapolated over the prior 10 years. While this is a very small number in any given year, in aggregate, it represents a continuing problem, and the state's numbers show a continuing trend of injuries each season. State law requires all accidents involving personal injury to be reported to OPRHP and 14 fatalities were reported to the state in the 2012–2013 year. These are 14 lives that could have potentially been saved with proper training, education, and safety equipment.

The patient demographics of the present study are in accordance with data from similar series of recreation-related trauma.^[3,5,7-10,12-20] There was both a great gender and age bias among the snowmobile-injured population, with 90% of injured riders being males and the mean age being 34.4 years (range 10-70). The age and gender disparity is important to note, as Mehus *et al.* found that perceptions of and communication about snowmobile-related risk was gender dependent. Men did not spontaneously relate risks to their snowmobile activities, whereas women did.^[15] Further, women talked about risks, were aware of risks, and sought to avoid risky situations. In contrast, men focused on how to manage challenging situations and how to maintain control while simultaneously testing their limits.^[15] We feel there is an opportunity here for targeted risk reduction education among males in the second and third decades. Such educational programs would need to take into consideration the varying gender attitudes toward safe snowmobile practices. These programs could be incorporated into the current training programs, similar to safety lectures during driver's education classes in high schools, or could be novel courses required for certification. Similar "safe driving" programs exist to reduce license points in many states, including New York, and could be easily translated to snowmobiling.

There have been many prior studies evaluating the incidence, type, mechanism, and outcomes of pediatric snowmobile-related trauma.^[7,16,19] In agreement with this work, of the 107 patients in the current study, 7% were younger than age 16. In 2000, the American Academy

of Pediatrics (AAP) issued a set of recommendations regarding the use of snowmobiles among children less than 18 years of age.^[2] The recommendation for children less than age 16 was that the recreational use of snowmobiles was inappropriate, and further that children less than 6 years of age lack the necessary strength and stamina to be safely transported as passengers on snowmobiles.^[2] For children greater than 16 years of age, the AAP recommends that there should be a graduated licensing system for snowmobile operators, snowmobilers should only travel at safe speeds, snowmobilers should avoid the use of drugs or alcohol before or during the operation of a snowmobile regardless of age, and all snowmobilers or operators should wear helmets approved by Snell or another standards organization.^[2] As snowmobiles have the capability of achieving high speeds (as fast as cars, or faster, depending on the model), allowing younger children to operate these machines is a risky proposition and re-examining these regulations to be more stringent on what age groups are allowed to operate these vehicles.

As head injuries are the leading cause of snowmobile-associated morbidity and mortality among pediatric populations, it is reassuring to know that New York State requires anyone driving or riding on a snowmobile, regardless of age, to be wearing an approved safety helmet while on public lands.^[1] However, in discordance with this set of guidelines, New York State law states that children between 14 and 17 years of age may operate a snowmobile on public lands without adult or other supervision provided they have completed a snowmobile safety course recognized by the state of New York.^[1] Furthermore, if a child is between 10 and 13 years of age they may operate a snowmobile on public lands if they have completed a snowmobile safety training course recognized by New York State and are within 500 feet of a person who is at least 18 years of age.^[1] Children under 10 years old or under 14 years of age and without a safety certificate may operate a snowmobile on lands owned or leased by a parent or guardian.^[1] A more comprehensive set of regulations requiring the use of helmets by riders of all ages, regardless of geography and land ownership, is needed to simplify regulations and encourage compliance.

The AAP has stated that there is insufficient scientific evidence that operator safety education courses adequately educate children as a strategy of snowmobile-related injury prevention.^[2] Further, Burgus *et al.* found that all-terrain vehicle safety education was actually associated with an increase in injuries in a pediatric population.^[5] The present study's data is in line with this AAP position, as evidenced by the fact that though New York State requires snowmobile operator safety training for all children and adolescents under 16 years of age, there is still a relatively high proportion of our injured

population represented by patients less than 16 years old. Nevertheless, we feel that appropriate education, targeted to addressing high-risk behaviors and ways to reduce injuries, should continue to occur. Further studies can be performed to investigate why safety education programs are associated with higher pediatric injuries with other recreational vehicles and ways to improve those programs to make a more meaningful reduction in pediatric injuries.

Since 43% of snowmobile-related incidents occur on privately owned property,^[10] and New York State legislation does not require operator safety training nor helmet use for snowmobilers on private lands, we must acknowledge that the injured children in the current study may not have benefited from a compulsory safety education course or helmet use. It is our recommendation then that more be done to bring current New York State snowmobile legislation in line with the AAP position statement on snowmobile use in children and adolescents, that this new legislation be applied universally to not only public but also private lands, and that there be a greater effort by law enforcement to ensure that these laws are being adhered to by children as well as their parents and guardians.

The present study was also able to demonstrate that head injuries occurred in 35% of patients with the spectrum including concussions, intracranial hemorrhages, and facial/skull fractures. Spinal injuries were also contributory in 21% of the patients evaluated. Legislation in New York State currently mandates that all operators and riders of snowmobiles on public land wear an approved safety helmet.^[1] However, Bjornstig *et al.* found that having a helmet law in place does not necessarily increase helmet use and consequently may only have a negligible injury-reducing effect.^[4] This may help explain why, in light of having law in place for compulsory helmet use, there is still a large proportion of the study population suffering a wide spectrum of neurologic injury secondary to head trauma. In the end, the responsibility rests with the riders and operators to wear helmets, whether on public or private lands, and engage in safe practices. While there are laws present, these studies have clearly demonstrated they are not an adequate deterrent to unsafe behavior on snowmobiles. While a large number of patients in our study did not have documentation in regard to helmet use, it is reasonable to hypothesize one of two things: Either these patients did not wear helmets, or they were injured despite helmet use. If the former is true, perhaps usage of helmets and other protective gear could have prevented injuries. If the latter is true, it supports the notion that helmet use alone is not sufficient, and more comprehensive education on safe practices, including the avoidance of risky, unsafe behaviors, is also needed. Neurosurgeons, as physicians with extensive experience with brain trauma, can take the

lead in their communities to educate riders, especially younger ones, on the risks associated with snowmobile use and ways to limit that risk while enjoying the sport.

Multiple studies recognize lack of helmet use, exceeding safe operating speeds, operating under poor lighting or trail conditions, and operating under the influence of ethanol or drugs as the leading modifiable risk factors responsible for snowmobile-related morbidity and mortality.^[3,8,10,11,13,17,22,23] As previously thought, stated compulsory helmet use laws are not necessarily effective at reducing snowmobile-associated injury. As such, there may be limited evidence that snowmobile safety education courses are effective at injury prevention in adult populations. Williams *et al.* was able to show that the use of a brief all-terrain vehicle safety (ATV) video integrated as part of a hunter education course increased ATV safety knowledge on most measures.^[24] Again, neurosurgeons can act as leaders in the community to promote or provide materials for these courses.

Currently, anyone who is a minimum 18 years old may operate a snowmobile in New York State without any other qualification, and it is only recommended that all operators complete a recognized snowmobile safety course.^[1] Considering that between 1993 and 1994 the injury, death, and hospitalization rates for snowmobiles was greater than that for on-road motor vehicles in the state of Alaska,^[13] it is concerning that qualification standards for snowmobiles are today still vastly less stringent. There are extensive training requirements and regulations present for driving motor vehicles on both public and private roads. Snowmobiles can often travel at similar speeds to cars, and even be operated on potentially unsafe terrain; however, only limited training is required for operating these vehicles, which lack the degree of safety equipment found in automobiles. It is our recommendation that more be done to increase competency thresholds for snowmobile operation as well as to strengthen and enforce legislation surrounding helmet use, speed limits, and operation under the influence of ethanol or drugs. Novel enforcement strategies that have been identified in the literature include increasing patrol services of both public and private trails, as well as collaboration between municipal police and local snowmobile clubs, delegating some enforcement authority to club members.^[10] Overall, such strategies to prevent neurological injury can reduce healthcare costs and the financial burden to society as a whole.

Finally, while neurosurgeons are most focused on injuries to the central and peripheral nervous system, it is important to highlight the other the nonneurologic injuries associated with snowmobiling. In this study, thoraco-abdominal solid organ and nonspinal orthopedic injuries were seen in patients in isolation and in combination with injuries to the nervous system. While it

is certainly tempting to focus on obvious cranial or spinal injuries, the principles of trauma management should not be forgotten, and a complete trauma survey must be undertaken on every trauma patient. Neurosurgeons should follow their institutional policies for trauma management (either by the emergency room physician or a dedicated trauma surgery service) and ensure that potentially life-threatening injuries are managed first before attention is turned to the secondary survey and the nervous system.

In our study, 19% of patients presented with a pneumothorax or hemothorax and chest tube placement. These can be rapidly fatal if not recognized early and treated. Twenty percent of patients had injuries to intraabdominal solid organs, which require close observation, and in some cases, surgical repair; three patients required a splenectomy, one patient needed a small bowel resection, and another required a colectomy with colostomy creation. While cranial injuries can be significant causes of morbidity and mortality, following trauma protocols and performing necessary radiographic studies or procedures before rushing to treat the neurosurgical injury can ensure other life-threatening injuries are not ignored or missed.

CONCLUSION

Snowmobiles are a significant source of multi-trauma, particularly neurological injury, in both adult and pediatric populations. Young adult males are a particularly high risk demographic for snowmobile-related injury, and more needs to be done to target this population for injury prevention strategies. Additionally, greater effort should be devoted toward policy, which brings current New York State snowmobile legislation in line with the AAP position statement on snowmobile use in children and adolescents, that this new legislation be applied universally to not only public but also private lands, and that there be a greater effort by law enforcement to ensure that these laws are being adhered to by all riders, especially children. Furthermore, regardless of age, competency thresholds for snowmobile operation must be made more stringent, and there must be increased efforts to strengthen and enforce legislation surrounding helmet use, speed limits, and operation under the influence of ethanol or drugs.

As physicians with extensive experience in nervous system trauma, and often the ones who treat injuries resulting from snowmobile accidents, neurosurgeons can play powerful roles in shaping educational programs and legislative action as in other sports (e.g., football). Neurosurgeons can use their patient data to promote safe riding practices within their communities and play key roles in advocating for neurological safety in snowmobiling.

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